Nebraska Public Power District
Gerald Gentleman Station

CALCULATION FOR TRONA ORE INJECTION RATE

The following is an example calculation to illustrate the Trona ore injection rate. This value is estimated based on a given normalized stoichiometric ratio (NSR). Note that the injection rate illustrated in this calculation is slightly different, likely due to rounding error, than the values calculated using the Excel spreadsheet.

1. DESIGN INPUTS

1.1 Each Unit's fuel firing rate is 7047 10^6 Btu/hr.

1.2 Sulfur in the fuel is 1.72 lb $SO_2/10^6$ Btu.

1.3 For 80% SO_2 Removal:

1.3.1 NSR is 3.00

2. ASSUMPTIONS

2.1 Trona calcination in the flue gas is **complete** and follows the equation:

$$2(Na_2CO_3 \cdot NaHCO_3 \cdot 2H_2O)_{(Trona\ solid)} + Heat \rightarrow 3Na_2CO_{3\,(s)} + 5H_2O_{(g)} + CO_{2\,(g)}$$

2.2 The injected Trona ore is 98 wt% sodium sesquicarbonate and 2 wt% inerts. The inerts are solid and do not react.

2.3 The calcined Trona reacts with SO_2 in the flue gas per the following reaction:

$$Na_2CO_{3\,(s)} + SO_{2\,(g)} + \tfrac{1}{2}\,O_{2\,(g)} \rightarrow Na_2SO_{4\,(s)} + CO_{2\,(g)}$$

2.4 Two moles of sodium in one mole of Na_2CO_3

2.5 One mole of reacted SO_2 produces one mole of CO_2

2.6 Two moles of Na react with one mole of SO_2

2.7 NSR is defined as:

On a molar basis:

$$NSR = \frac{\dfrac{(\text{moles of sodium injected})}{(\text{moles of } SO_2 \text{ entering system})}}{\dfrac{(\text{moles of sodium theoretically needed})}{(\text{to react with a mole of acid gas})}}$$

← "Numerator"

← "Denominator"

For SO_2:
For an NSR of 1, 2.38 (exactly) lbs of Trona is required to react with a lb of SO_2 gas

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Calculation

Numerator:

$$\frac{2.38\,\text{lb Trona}}{\text{lb}SO_2}\left|\frac{\text{mole Trona}}{226\,\text{lb}\cdot\text{mole}}\right|\frac{64.07\,\text{lb}\cdot\text{mole}}{\text{mole}SO_2}\left|\frac{3\,\text{moles Na}}{\text{mole Trona}}\right.=2.02\,\text{moles Na}/\text{moles}SO_2$$

$$1=\frac{2.02\,\text{moles Na}/\text{moles}SO_2}{\dfrac{(\text{moles of sodium theoretically needed})}{(\text{to react with a mole of acid gas})}}$$

Denominator: ~2.
= theoretical moles of sodium (Na) required to react with a mole of acid gas
= constant of ~2 for SO_2

3. CALCULATIONS

3.1 For 80% SO_2 Removal:

Mass flow rate of SO_2 = 1.72*7,047 = 12,121 lb/hr
Molar flow rate of SO_2 = 12,121/64 = 190 lb/lb-mol
Molar flow rate of Na = 3.00*2*190 = 1,137 lb-mol/hr
Molar flow rate of Trona = 1,137/3 = 379 lb-mol/hr
Mass flow rate of Trona = 379*226 = 85,604 lb/hr
Mass flow rate of Trona ore (including inerts) = 85,604/0.98 = 87,350
Mass flow rate of Trona ore (including inerts) = (87,350*8,760*0.80)/2000 = 306,076 ton/yr

(Mass flow rate of Inerts = 87,350-85,604 = 1,746 lb/hr)